Stoller
Hanford Office

DOE-EM/GJ827-2005

C4671
Log Data Report

Borehole Information:

Borehole: C4671			Site: 216-A-4 Crib		
Coordinates (WA State Plane)		GWL (ft)[1]: 233.4		GWL Date: 07/22/2004	
North	East	Drill Date	TOC[2] Elevation	Total Depth (ft)	Type
Not available	Not available	08/26/2004	Not available	60	Direct Push

Casing Information:

Casing Type	Stickup (ft)	Outer Diameter (in.)	Inside Diameter (in.)	Thickness (in.)	Top (ft)	Bottom (ft)
Threaded steel	0.0	6 5/8	5 3/8	0.625	0	60
The logger used a caliper and steel tape to measure outside and inside casing diameter. All measurements were rounded to the nearest 1/16-in.						

Borehole Notes:

Zero reference is the ground surface. C4671is a direct push hole installed approximately 4 ft away from borehole C4560 to investigate unanticipated high contamination levels encountered at about 20 ft below ground surface as the hole was being drilled. Because C4671 was driven as a sealed tube, it was considered to be a "low risk" borehole and was not swabbed prior to logging.

Logging Equipment Information:

Logging System:	Gamma 4E		Type: 70% HPGe (34TP40587A)
Calibration Date:	07/2004	Calibration Reference:	DOE/EM-GJ692-2004
		Logging Procedure:	MAC-HGLP 1.6.5, Rev. 0

Logging System:	Gamma 1C		Type: "Planar" HPGe (39A314)
Calibration Date:	09/2004	Calibration Reference:	DOE/EM-GJ713-2004
		Logging Procedure:	MAC-HGLP 1.6.5, Rev. 0

Logging System:	Gamma 4L		Type: ^{3}He detector (U1754)
Calibration Date:	N/A	Calibration Reference:	N/A
		Logging Procedure:	MAC-HGLP 1.6.5, Rev. 0

Spectral Gamma Logging System (SGLS) Log Run Information:

Log Run	1	2	3	4	5
Date	09/01/04	09/01/04	09/01/04	09/01/04	09/01/04
Logging Engineer	Spatz	Spatz	Spatz	Spatz	Spatz
Start Depth (ft)	58.0’	49.0’	47.0’	11.0’	8.0’
Finish Depth (ft)	48.0’	47.0’	10.0’	0	2.0’
Count Time (sec)	20 s	100 s	20 s	100 s	100 s
Live/Real	R	R	R	R	R
Shield (Y/N)	NA	NA	NA	NA	NA
MSA Interval (ft)	1.0’	1.0’	1.0’	1.0’	1.0’
ft/min	NA	NA	NA	NA	NA
Pre-Verification	DE321CAB	DE321CAB	DE321CAB	DE321CAB	DE321CAB
Start File	DE321000	DE321012	DE321015	DE321053	DE321065
Finish File	DE321011	DE321014	DE321052	DE321064	DE321071
Post-Verification	DE321CAA	DE321CAA	DE321CAA	DE321CAA	DE321CAA
Depth Return Error (in.)	N/A	N/A	N/A	0	0
Comments	High rate interval	No fine gain adjustments made	High rate interval	No fine gain adjustment made	Repeat interval

High Rate Logging System (HRLS) Log Run Information:

Log Run	6	7	8	9	10
Date	09/02/04	09/02/04	09/02/04	09/02/04	09/02/04
Logging Engineer	Spatz	Spatz	Spatz	Spatz	Spatz
Start Depth (ft)	58.0'	52.0'	46.0'	42.0'	36.0'
Finish Depth (ft)	52.0'	46.0'	42.0'	36.0'	26.0'
Count Time (sec)	100 s	300 s	100 s	300 s	100 s
Live/Real	R	R	R	R	R
Shield (Y/N)	None	None	None	None	None
MSA Interval (ft)	1.0’	1.0'	1.0'	1.0'	1.0’
ft/min	NA	NA	NA	NA	NA
Pre-Verification	AC109CAB	AC109CAB	AC109CAB	AC109CAB	AC109CAB
Start File	AC109000	AC109007	AC109014	AC109019	AC109026
Finish File	AC109006	AC109013	AC109018	AC109025	AC109036
Post-Verification	AC109CAA	AC109CAA	AC109CAA	AC109CAA	AC109CAA
Depth Return Error (in.)	NA	NA	NA	NA	NA
Comments	No fine gain adjustment made	No fine gain adjustment made	No fine gain adjustment made	No fine gain adjustment made	No fine gain adjustment made

Log Run	11	12	13	14
Date	09/02/04	09/02/04	09/02/04	09/02/04
Logging Engineer	Spatz	Spatz	Spatz	Spatz
Start Depth (ft)	26.0'	16.0'	27.0'	23.0'
Finish Depth (ft)	13.0'	13.0'	16.0'	18.0'
Count Time (sec)	20 s	300 s	100 s	100 s
Live/Real	R	R	R	R
Shield (Y/N)	None	None	Both internal & external	Both internal & external
MSA Interval (ft)	1.0'	1.0'	1.0'	1.0’
ft/min	NA	NA	NA	NA
Pre-Verification	AC109CAB	AC109CAB	AC109CAB	AC109CAB
Start File	AC109037	AC109051	*AC109055	*AC109067
Finish File	AC109050	AC109054	AC109066	AC109072
Post-Verification	AC109CAA	AC109CAA	AC109CAA	AC109CAA
Depth Return Error (in.)	NA	-1"	NA	0
Comments	High-high rate interval	No fine gain adjustment made	No fine gain adjustment made. *For these spectra, a centralizer was not installed on the sonde	Repeat section. *For these spectra, a centralizer was not installed on the sonde

Passive Neutron Logging System (PNLS) Log Run Information:

Log Run	15	16		
Date	09/08/04	09/08/04		
Logging Engineer	Spatz	Spatz		
Start Depth (ft)	0.0'	15.0'		
Finish Depth (ft)	58.0'	30.0'		
Count Time (sec)	15 s	15 s		
Live/Real	R	R		
Shield (Y/N)	None	None		
MSA Interval (ft)	N/A	N/A		
ft/min	1.0	1.0		
Pre-Verification	DL072CAB	DL072CAB		
Start File	DL072000	DL072233		
Finish File	DL072232	DL072293		
Post-Verification	DL072CAA	DL072CAA		
Depth Return Error (in.)	NA	NA		
Comments	None	Repeat section		

Logging Operation Notes:

Pre- and post-survey SGLS verification measurements were acquired in the Amersham verifier. Unusually high levels of activity (approximately 34 cps) from the 662 keV gamma line associated with ^{137}Cs were observed in both the pre-run and post-run verification spectra on September 1, 2004. At the time, this was attributed to ambient levels related to near-surface contamination or “shine.” Logging was performed with a centralizer on the sonde. Maximum log depth was 58.41 ft.

The Gamma 4E system was next used to log C4176 at the 216-S-20 Crib on September 14, 2004. At that time, contamination was detected on the sonde by the logging engineer. Radiological surveys on September 15 found contamination on the wipes used to clean the logging sonde and cable and on the gloves and clothing of a logging engineer. Subsequent investigation indicated that the contamination originated in borehole C4671. A borehole swab detected contamination on the inside of the casing at C4671. The passive neutron sonde and the external shield for the high rate logging sonde were also found to be contaminated, and contamination was found on the drive head of the push rig. Prior to logging C4671, the Gamma 4E system had been used to log C3426 (299-W15-46) on August 31, 2004. Although the upper part of this hole had penetrated significant contamination, the August 31 log event was performed inside a second casing string, which was installed specifically to isolate subsurface contamination. Only negligible levels of activity related to the 662 keV photopeak were observed in the pre-run and post-run verification spectra at that borehole.

All available data indicate the presence of contamination on the inside of the casing at C4671 prior to logging on September 1, 2004. Visual inspection with a borehole television camera on January 25 indicated that the casing appears to be intact and the bottom plug is in place. The source of the internal contamination in C4671 is unknown. A more detailed discussion of the contamination incident is attached.

High rate logging was performed from 13 to 58 ft. Both the internal and external tungsten shields were used from 16 to 27 ft (log runs 13 and 14) in the depth interval of highest gamma activity. The pre- and post-verification measurements for the high rate system were acquired in the CS-137 verifier, SN 1013.

The passive neutron log was run over the entire length of the borehole. This log detects neutrons originating from (α, n) reactions between alpha particles emitted by radioactive decay of heavy elements and light elements such as oxygen in the soil. It is considered useful as a qualitative indicator of the presence of transuranic (TRU) radionuclides.

C4671 was classified as "low risk," and radiological support was not provided during logging operations. High ambient levels of ^{137}Cs activity were detected in the verifier both before and after logging operations. This effectively masked the contamination on the sonde, and it was not discovered until the logging system was next deployed at C4176, approximately two weeks later.

Analysis Notes:

Analyst:	McCain/Henwood	**Date:**	2/10/05	**Reference:**	GJO-HGLP 1.6.3, Rev. 0

SGLS pre- and post-run verification spectra were collected in the Amersham verifier at the beginning and end of each day. Both net count rate and FWHM were compared to verification criteria for gamma activity at 609, 1461, and 2615 keV. In general, the spectra exhibited minor loss of efficiency and peak spreading, particularly at higher gamma energies. Net count rates for the 609, 1461, and 2615 keV photopeaks were 7.4, 8.8, and 10.4 percent lower in the post-run verification, relative to the pre-run verification. Net count rates for the 2615 peak were slightly below the lower control limit, but well within the 20% HASQARD criteria. Visual examination of the verification spectra indicated the detector is functioning normally, and the results are provisionally accepted.

As noted above, unusually high levels of gamma activity at 662 keV were observed in both the pre- and post-run verification spectra. Preliminary inspection indicated approximately the same count rate in both spectra, and the activity was attributed to ^{137}Cs contamination at or near the ground surface or "shine" from nearby contamination. Closer inspection of the spectra indicated that overall detector efficiency declined by about 7 to 10 percent between the pre- and post-run verification spectra. This degree of change over the course of a day is not unusual. If the net count rate at 662 keV is evaluated in terms of the decreasing efficiency, a net increase of about 2.6 cps was observed. This supports the finding that the contamination originated in borehole C4671.

Log spectra for the SGLS were processed in batch mode using APTEC SUPERVISOR to identify individual energy peaks and determine count rates. Pre-run verification spectra were used to determine the energy and resolution calibration for processing the data using APTEC SUPERVISOR. Concentrations were calculated in EXCEL (source file: G4Ejul04.xls), using parameters determined from analysis of recent calibration data. Zero reference was the ground surface. The casing configuration was assumed to consist of 6-inch ID casing from surface to 60 ft. A correction factor for casing thickness of 0.625 in. was used over the entire borehole. Dead time corrections were applied to the SGLS data where dead time exceeded 10 percent. Where SGLS dead time exceeds 40 percent, HRLS data are substituted. No water correction was applied.

High rate log spectra were processed in batch mode using APTEC SUPERVISOR to identify individual energy peaks and determine count rates. Verification spectra were used to determine the energy and resolution calibration for processing the data using APTEC SUPERVISOR. Concentrations for HRLS spectra were calculated in EXCEL (source file G1cMay04.xls). Logging was conducted in a single casing string for each log run. A correction for a 0.625-in.-thick casing was applied to the HRLS data. Dead time corrections are applied to the HRLS data where dead time exceeds 10.5 percent. Where HRLS dead time exceeds 30 percent, shields are used to reduce dead time and a shield correction factor is applied. Both internal and external shield were used in the interval from 16 to 27 ft. No water corrections were required.

The passive neutron log is presented as raw count rate vs. depth, and the log is intended for qualitative evaluation only. However, the ^{3}He detector used in the passive neutron log is known to be affected by high gamma flux (Knoll 2000) and it is highly probable that the high neutron count rates reported between 12 and 29 ft are associated with high gamma activity and do not represent the presence of TRU. A plot showing PNLS response plotted as a function of ^{137}Cs activity is attached. For ^{137}Cs concentrations above 10^{6} pCi/g, there appears to be a correlation between passive neutron count rate and ^{137}Cs concentration. Therefore, the neutron anomaly between 15 and 28 ft appears to be primarily the result of gamma activity and not TRU. Minor passive neutron activity at 45 and 55 ft is also probably due to high gamma levels.

Log Plot Notes:

Separate log plots are provided for gross gamma and dead time, naturally occurring radionuclides (^{40}K, ^{238}U, and ^{232}Th), and man-made radionuclides. Repeat logs for man-made radionulcides are included for the SGLS and the HRLS. For each radionuclide, the energy value of the spectral peak used for quantification is indicated. Unless otherwise noted, all radionuclides are plotted in picocuries per gram (pCi/g). The open circles indicate the minimum detectable level (MDL) for each radionuclide. Error bars on each plot represent error associated with counting statistics only and do not include errors associated with the inverse efficiency function, dead time correction, or casing correction. A combination plot is also included to facilitate correlation. An additional combination plot is provided to show the passive neutron log with total gamma, dead time, and ^{137}Cs concentration.

Results and Interpretations:

^{137}Cs was the only man-made radionuclide detected in this borehole. ^{137}Cs was detected at the ground surface at a concentration of 60 pCi/g. Between ground surface and 12 ft, concentrations varied from 36 to 80 pCi/g. Beginning at 12-ft depth, ^{137}Cs concentration increases rapidly to a maximum value of approximately 2.36 x 10^{8} pCi/g at 20-ft depth. The zone of maximum concentration appears to be less than 1 ft thick. Between 20 and 32 ft, ^{137}Cs concentrations decrease to between 10^{3} and 10^{4} pCi/g and remain in this range to total depth at 58 ft. Sharp peaks occur at 35, 45, and 55 ft; these may be related to accumulated contamination at casing joints. As discussed above, this boring is known to have significant internal contamination, and at least some of the observed contamination can be attributed to internal casing contamination and/or sonde contamination. Assuming the contamination on the sonde (as determined from pre- and post-run verification spectra) is equivalent to about 2.6 cps for the 662 keV photopeak, this is equivalent to an "apparent" ^{137}Cs concentration of about 1.7 pCi/g. Clearly, this represents a relatively insignificant effect on the total concentrations reported in the log. The contribution from contamination on the sonde also appears to be significantly less than total contamination levels measured in the borehole,

suggesting that the effects of internal casing contamination are much greater than that of sonde contamination. The contamination observed at 55 ft (approximately 10^6 pCi/g) probably represents the highest level that can be attributed to internal contamination. The intense gamma activity at 20 ft strongly suggests a relatively thin layer of extremely high levels of ^{137}Cs contamination. Even assuming that the effects of internal casing contamination contribute to "apparent" concentrations on the order of 10^3 to 10^6 pCi/g, the effect on ^{137}Cs levels at 20 ft would still be less than 1 percent.

The passive neutron log appears to have been affected by high gamma activity and should not be considered a reliable indicator of TRU in this borehole. Careful examination of HRLS spectra at 20 ft fails to show any gamma lines indicative of ^{239}Pu or other transuranics. However, it is likely that the intense radioactivity associated with ^{137}Cs, as well as attenuation in the tungsten shielding, would effectively mask the presence of lower-energy gamma lines typical of TRU. HRLS spectra collected with both shields exhibit low-energy gamma lines, which are attributed to the characteristic K_α and K_β fluorescence lines for tungsten.

The passive neutron log also exhibits a value of 10 cps at ground surface, decreasing to less than 0.1 cps at 3-ft depth. The source of this activity is not known. SGLS spectra from this depth range show no evidence of gamma lines indicative of transuranic elements. For ^{239}Pu, the minimum detection limit is estimated to be about 85,000 pCi/g, based on the 375 keV line.

Repeat logs for the SGLS demonstrate good repeatability for the natural radionuclides (1461, 1764, and 2614 keV). However, the repeat plot for ^{137}Cs (662 keV) shows an average decrease of approximately 34 percent in the repeat log relative to the original log. This discrepancy is highly unusual, and an effort was made to assess the possible cause. In C4671, the repeat section was collected in the borehole interval between 2 and 8 ft. The original log data were collected in run 4, which extended from 11 ft to ground surface. The logging engineer immediately lowered the sonde to the 8-ft depth and logged the repeat section from 8 ft to 2 ft. Time stamps on the field spectra files indicate that only 3 minutes elapsed from the last measurement of run 4 at the ground surface (DE321064) and the first run of the repeat section (DE321065). The elapsed time between the original measurement in the repeat interval (DE321056 at 8 ft) and the last repeat measurement (DE321071 at 2 ft) is approximately 27 minutes. Within this time period, loss of efficiency in the detector should have been negligible, and the agreement in natural radionuclides supports this observation. Comparison of individual spectra also indicates that the only significant change is a loss of counts within the 662 keV photopeak. Collectively, these observations indicate that the detector continued to function normally, and that at least some of the contamination on the sonde (or on the inside of the casing within the repeat interval) was dislodged between completion of log run 4 and the beginning of log run 5. The nature of this contamination, or the mechanism by which it was dislodged, is not known.

Repeat logs for the HRLS demonstrate excellent repeatability for the ^{137}Cs measurement in the high activity interval.

References:

Fecht, K.R., G.V. Last, and K.R. Price, 1977. *Evaluation of Scintillation Probe Profiles from 200 Area Crib Monitoring Wells*, ARH-ST-156, Atlantic Richfield Hanford Company, Richland, Washington.

Knoll, G F, 2000. *Radiation Detection and Measurement*, 3rd Edition, New York, New York.

Evaluation of Sonde Contamination Incident in Boreholes C4176 and C4671

Introduction

On September 15, 2004, radioactive contamination was detected on the spectral gamma logging system (SGLS) designated Gamma 4E while logging in borehole C4176, near the 216-S-20 Crib. Evaluation of the log data showed that the sonde was contaminated with residual ^{137}Cs, and that data collected in borehole C4176 between 241 and 66 ft on September 14, 2004 are suspect. This incident prompted a thorough investigation of recent log data to determine how the sonde became contaminated and to assess any effect this contamination may have had on other borehole logs. This document summarizes findings and provides recommendations to avoid future occurrences.

Evaluation of Log Data

Log data for borehole C4176 are shown in Figure 1. For discussion purposes, the logging activities are broken down into three separate events, with individual runs within each event identified by letters. All log runs were made with SGLS Gamma 4E.

Date	Event	Depth Interval
August 26	Run 1	53 – 0 ft
September 14	Run 2a	241 – 66 ft
September 15	Run 2b	87 – 52 ft
September 28	Run 3a	0 – 235 ft
September 29	Run 3b	240.4 – 220 ft

Borehole C4176 was drilled with a cable tool rig in two stages, using telescoping casing to seal off contamination in the upper vadose zone. In the first stage, 10-3/4-in. OD casing was set at 55 ft. The borehole interval from 0 to 53 ft was logged on August 26, 2004 (Run 1). The SGLS detected high gamma activity from 20 to 35 ft. ^{137}Cs was detected at the ground surface and from 19 to 53 ft. Near the ground surface, 131 pCi/g was detected at 1-ft depth. The maximum concentration of 3,540 pCi/g was detected at 24-ft depth. An additional peak was observed at 51 ft with a maximum concentration of 73 pCi/g. ^{60}Co was detected from 33 to 38 ft, with a maximum concentration of 1.4 pCi/g at 33 ft. Lesser amounts of ^{60}Co were detected at 41 and 43 ft and from 50 to 52 ft. ^{234m}Pa (an indicator of anthropogenic ^{238}U) was detected from 33 to 40 ft, with a maximum concentration of 201 pCi/g at 33 and 34 ft. It is likely that both ^{60}Co and ^{238}U also exist with the high ^{137}Cs interval from 20 to 33 ft, but they are not detected because of the intense gamma activity associated with ^{137}Cs. Fecht et al. (1977) reports Pu, Sr, ^{137}Cs, ^{60}Co, and U as potential contaminants at the 216-S-20 Crib.

^{137}Cs was also detected in both the pre- and post-run verification spectra. This was attributed to "shine" from surface contamination. This is a relatively common occurrence and the presence of a 662 keV peak from ^{137}Cs in the verification spectra was not considered unusual, especially since the log showed relatively high values close to the surface.

An 8-5/8-in. OD casing was used to advance the borehole from 55 to 245 ft in depth. On September 14, 2004, the hole was logged inside the 8-5/8-in. casing (Run 2a). Since the hole was considered "low risk," no attempt was made to swab the casing prior to logging. ^{137}Cs was again detected in the pre-run verification spectra, but this was not considered unusual since the counts were comparable to those seen previously (3.72 cps, compared to 3.99 cps). The sonde was lowered to the bottom of the hole at 241 ft and logging proceeded upward to 66 ft. Significant ^{137}Cs was noted at the bottom of the hole and in all subsequent log spectra collected on that day, as well as in the post-run verification spectra (2.6 cps). A well-defined peak was present at 662 keV in all spectra, and the net count rate for the 662-keV peak varied from 2.5 to 7.1 cps, with a mean value of 3.4 cps. This is equivalent to a persistent apparent ^{137}Cs concentration on the order of 1.3 to 3.8 pCi/g, and is consistent with the net count rates of 3.7 and 2.6 cps observed in the pre-run and post-run verification spectra.

During the logging operation, the logging engineer wiped the cable as it was withdrawn from the borehole. After approximately 60 ft of logging (sonde at about 180-ft depth), the logging engineer was replaced. The sonde was withdrawn from the hole at the end of the day and a post-run verification spectrum was collected. ^{137}Cs was also noted in the post-run spectrum. The following day (September 15), a pre-run verification spectra was collected and the sonde was lowered to a depth of 87 ft and logging proceeded upward to 52 ft (Run 2b). The interval from 87 to 67 ft was labeled as a repeat section, since it had been logged the previous day. While logging operations were underway, radiological control technicians (RCTs) were notified to survey the wipes used to clean the cable, sonde, and centralizer from the previous day. Contamination was found. The gloves of both logging engineers were also contaminated. The sonde was left inside the borehole while a complete radiation survey of the logging system was performed. When the sonde was removed from the borehole, the centralizer was contaminated. A post-run verification spectra was not collected on this day because of the delay in removing the sonde from the borehole. Evaluation of log data for September 15 (Run 2b) does not show evidence of sonde contamination. Apparent ^{137}Cs concentrations in the repeat interval are at or near the MDL of approximately 0.2 to 0.3 pCi/g. A borehole swab in C4176 after the logging events did not detect any evidence of contamination.

On September 28 and 29, 2004, borehole C4176 was re-logged after it had been determined that log data collected on September 14 was affected by contamination on the sonde. Run 3a on September 28 extended from the ground surface to 235 ft. After logging was completed, the cable was checked for contamination as the sonde was withdrawn from the hole. None was found. Run 3b was made on September 29. In this run, the sonde was allowed to touch bottom and the hole was logged from 240.4 to 220 ft. Total depth of the hole was 240.4 ft on September 29, compared to 241.0 ft on September 14. Pre- and post-run verification spectra collected on September 28 and 29 show only trace amounts of ^{137}Cs. A background spectrum collected prior to logging on September 29 also shows only minor ^{137}Cs activity, which can be attributed to "shine." ^{137}Cs was detected at the bottom of the hole at an apparent concentration of 3.5 pCi/g. This is very close to the value observed at the bottom of the hole on September 14. ^{137}Cs was also detected from 231 to 233 ft, with a maximum concentration of about 0.6 pCi/g, and from 156 to 157 ft, with a maximum concentration of about 0.33 pCi/g. The peak from 156 to 157 ft corresponds to an increase in ^{137}Cs observed on the September 14 log.

Probable Source of Contamination

When the sonde was examined after logging on September 15, sandy material on the centralizer was found to be contaminated. This material most likely originated from borehole C4176, and it is likely that contaminated material was encountered near the bottom of the hole. Material lost from the drive barrel during sampling may have contributed to low levels of internal contamination in C4176. Both the "contaminated" SGLS log on September 14 and the repeat log on September 28 consistently detected ^{137}Cs at the bottom of the hole and from 156 to 157 ft.

Prior to logging at C4176, Gamma 4E had most recently been used to log borehole C4671 on September 1, 2004. This was a direct push tube (DPT) installed at the 216-A-4 Crib. It was installed approximately 4 ft away from borehole C4560, which had been suspended after unanticipated levels of subsurface contamination were encountered. C4671 was intended to investigate this contamination. It consisted of a 6-in.-diameter heavy wall steel casing with a solid tip driven into the ground. Because of the plug in the end of the casing, it was considered a "low risk" borehole even though it was known to penetrate significant contamination. ^{137}Cs concentrations in excess of 236 million pCi/g were measured in this borehole. This borehole was also logged with the high rate logging system and the passive neutron logging system. Further investigation showed that the passive neutron sonde and the external shield for the high rate logging system were also contaminated. A borehole swab in C4671 also indicated contamination.

From this information, it is concluded that the initial source of the sonde contamination was borehole C4671. However, the possibility of internal contamination in borehole C4176 remains probable, even though a borehole swab after logging operations failed to detect anything. Between logging events on September 14 and September 15, the cable, sonde, and centralizer were cleaned. The wipes and other material from this operation were bagged. When they were checked on September 15, contamination was

found. Comparison of log data from September 15 (run 2b) and September 14 (run 2a) clearly show that most, if not all, of the contamination on the sonde was removed by the cleaning. When the sonde was removed from the borehole on September 15, fine-grained material had accumulated on the centralizer; this material was found to be contaminated. Since the cleaning would have removed all visible material, it is almost certain that this material came from borehole C4176. This contamination is most likely related to material lost from drive barrels or samplers when the borehole was at or near total depth.

Evaluation of Verification Data

Investigation of the contamination incident led to evaluation of previous verification spectra. Table 1 summarizes borehole intervals logged with SGLS Gamma 4E between August 26 and September 29, 2004. This time period extends from the first log of C4176 through the final logging operations performed to replace suspect data, and lists all logs within that period. The radioactive contamination is known to be ^{137}Cs, so all verification spectra have been reprocessed to "force" a region of interest for the 661.62 keV gamma line from ^{137}Cs. In addition, the net count rate for the 1460.83 keV gamma line from ^{40}K (typically the most prominent peak in the verification spectrum) is shown, and the ratio between net count rate for the 662 peak vs. net count rate for the 1461 peak is also shown.

The presence of a 662-keV peak in verification spectra is not uncommon, and net count rates of 1 to 4 cps can be attributed to "shine," or ambient activity from surface contamination, or other sources unrelated to the logging activity. The exceptions are verification spectra collected on September 1, 2004, at borehole C4671. Net count rates of about 34 cps were observed for the 662 keV gamma line in both the pre-run and post-run verification spectra collected that day. Although this is substantially greater than normal, the fact that it appeared in the pre-run verification spectra indicated that there were unusually high ambient levels of ^{137}Cs. Since there appeared to be a slight decrease from the pre-run to the post run, the observed ^{137}Cs peak was attributed to "shine." However, it is known that the overall efficiency of the SGLS detector tends to decrease slightly over the course of a day. Therefore, the net counts at 662 keV were "normalized" relative to net counts for the ^{40}K peak at 1461 keV, which should be at a more consistent level. The change in this ratio indicates that an increase in the relative amount of ^{137}Cs occurred between the beginning and end of the log run on September 1, and suggests the sonde may have become contaminated in that borehole. Comparison of the 662 peak to the 1461 peak in the verification spectra leads to an estimated increase of about 2.6 cps in net activity for the 662 keV peak. However, the high "ambient" ^{137}Cs activity in the verification spectra (about 34 cps) masked this increase. When the sonde was next used in C4176 on September 14, the pre-run verification spectra had a 662 keV peak with a net count rate of 3.7 cps. This was comparable to typical values commonly attributed to "shine" at other locations and was actually less than the 4 cps observed in the verification spectra when C4176 was first logged on August 26. However, the minimum count rate for the 662 keV peak observed in log spectra collected on September 14 was 2.5 cps. This is roughly the same as the estimated net increase in ^{137}Cs activity observed on September 1, and leads to the conclusion that the sonde was contaminated in borehole C4671 on September 1, but was not detected until the logging system was next used in borehole C4176 on September 14.

The sonde was wiped down after the log run on September 14 and before logging on September 15. The wipes were contaminated. Log data collected on September 15 appears to be free of the "residual" ^{137}Cs activity noted on September 14, and it is concluded that most, if not all, of the contamination on the sonde was removed by routine wiping. The sonde was checked by RCTs after the log run of September 15, and no contamination was found. After C4176, the sonde was next used on September 22 in borehole C4665 (299-E25-95), a new groundwater well near AX Farm. ^{137}Cs activity was noted in both pre-run and post-run verification spectra, and the borehole log indicates a maximum ^{137}Cs concentration of 3.3 pCi/g at 4 ft, decreasing to below the MDL at about 25 ft. On the next day, the borehole interval below 260 ft was logged and only intermittent traces of ^{137}Cs at the MDL were found. This log profile is consistent with other logs in the area and does not appear to have been affected by any contamination on the sonde. On September 27, the sonde was used to log C4570 (699-17-27P) in the 100-K Area, and only intermittent traces of ^{137}Cs at the MDL were found. These are common in all logs at Hanford. During routine log processing, a region of interest (ROI) is "forced" for the ^{137}Cs peak at 662 keV and random fluctuations lead to intermittent traces where the net counts are at or slightly above the minimum detectable activity.

When these spectra are examined, there is no evidence of a peak at 662 keV and the traces are not considered statistically significant.

Conclusion and Recommendations

Available evidence indicates the SGLS Gamma 4E sonde was most likely contaminated from logging operations conducted in borehole C4671 on September 1. However, the contamination was not detected because of high ^{137}Cs concentrations throughout the borehole and very high "ambient" ^{137}Cs activity at the surface. Since C4671 was classified as "low risk," no radiological survey was performed and the contamination went undetected. When the sonde was next used on September 14 in borehole C4176, the ^{137}Cs activity observed in the pre-run verification spectrum did not appear unreasonable for "shine," but the persistent level of 2.5 to 3 cps throughout the logged interval clearly indicated the sonde was contaminated, and led the logging engineer to request a radiological survey of the wipes. Evaluation of verification spectra and log data collected on September 15 and afterward shows that the contamination was removed by routine wiping, and the sonde is no longer contaminated. Repeat logs in borehole C4176 indicate minor ^{137}Cs concentrations from 157 to 158 ft and near the bottom of the hole. The presence of contamination associated with fine-grained material on the centralizer after the log run on September 15 strongly suggests the presence of contaminated material on the inside of the 8-5/8-in. casing in borehole C4176. Before C4176 is abandoned, a sample should be collected from the bottom of the borehole and analyzed for comparison with the sandy material from the centralizer.

The relatively high background gamma activity at 662 keV effectively masked the presence of contamination on the sonde, but Stoller logging personnel quickly detected it when the sonde was next used.

Evaluation of verification spectra and log data collected since September 15 clearly shows that the sonde is no longer contaminated. However, the fact that contamination was picked up in a "low risk" borehole strongly suggests that all boreholes should be swabbed prior to logging, regardless of risk category. As an added precaution, geophysical logging personnel should have radiation detection instruments available at the logging site, so that suspected contaminated material can be more quickly identified and reported. These instruments are provided through the Grand Junction Office. It is not the intent to supplant the existing radiation control program, but to provide a means for early warning in low-risk situations where full-time RCT coverage is not practical.

Table 1. Summary of Gamma 4E Log Data from 8/26/04 to 9/29/04

Date	Borehole	Depth Interval	Verification Spectra	^{137}Cs (0662) & ^{40}K (1461) data			Discussion of Results
				0662 cps	1461 cps	0662/1461	
8/26/04	C4176	53-0 22-17	DE281CAB DE281CAA	3.99 3.95	20.89 20.80	0.191 0.190	Initial log run in C4176. 0662 peak typical of ^{137}Cs "shine. ^{60}Co, ^{137}Cs and ^{238}U (^{234m}Pa) detected. Maximum ^{137}Cs is 3541 pCi/g at 24 ft.
8/30/04	C4260 299-E33-48	287-59	DE291CAB DE291CAA	1.13 1.14	20.83 21.01	0.054 0.054	Only intermittent traces of ^{137}Cs at or near MDL
8/31/04	C4260 299-E33-48	138-115	DE301CAB DE301CAA	0.62 1.18	20.93 21.48	0.029 0.055	
8/31/04	C3426 299-W15-46	197-110 120-110	DE311CAB DE311CAA	0.40 0.74	20.79 20.16	0.019 0.037	Only intermittent traces of ^{137}Cs at or near MDL
9/01/04	C4671	58-48 49-47 47-10 11-0 8-2	DE321CAB DE321CAA	34.36 33.96	21.11 19.29	1.627 1.760	Multiple SGLS runs with varying count times to deal with high gamma activity and detector dead time. High ^{137}Cs in pre-run attributed to "shine." Extremely high levels of ^{137}Cs detected throughout the borehole. Loss of efficiency masks increase in ^{137}Cs on sonde in post-run. Net increase in 0662 approximately 2.6 cps. Borehole swabbed on 9/04 – evidence of contamination found. PNLS sonde and external shield for HRLS also found to be contaminated.
9/14/04	C4176	241-66	DE331CAB DE331CAA	3.72 2.60	20.91 19.69	0.178 0.132	^{137}Cs in verification spectra actually lower than previous (DE281CAB/CAA above) 0662 net counts varied from 2.51 to 7.12 cps, with average 3.39 cps and median 3.27 cps.
9/15/04	C4176	87-52	DE341CAB	1.18	20.56	0.057	Sonde was wiped down from previous day: wipes found to be contaminated (after DE341CAB). Evidence of borehole contamination from previous day discovered. Sandy material on centralizer found to be contaminated after log run. Borehole swabbed on 9/??/04 – no evidence of contamination.
9/22/04	C4665 299-E25-94	0-183 150-260	DE351CAB DE351CAA	3.81 3.20	20.93 20.68	0.182 0.155	Maximum ^{137}Cs concentration 3.3 pCi/g at 4 ft – decreases to MDL at about 25 ft. ^{137}Cs below MDL (0.22 pCi/g) at 1 ft. Observed contamination likely related to previous ground surface.
9/23/04	C4665 299-E25-94	259-326	DE361CAB DE361CAA	3.86 3.66	20.54 20.27	0.188 0.181	Traces of ^{137}Cs at MDL (0.17 – 0.22 pCi/g).
9/27/04	C4570 699-17-27P	0-26 22-19	DE371CAB DE371CAA	0.69 0	19.91 20.47	0.035 0	Only intermittent traces of ^{137}Cs at or near MDL.
9/28/04	C4176	0-235	DE381CAB DE381CAA	0.44 0.57	20.75 20.20	0.021 0.026	Results indicate bottom of 10 ¾ casing at 58 ft; lower extent of contaminated zone at 57 ft. ^{137}Cs at or below MDL below 57 ft. Possible ^{137}Cs at 156-157 ft.
9/29/04	C4176	240.4-220	DE391CAB DE391BAB DE391CAA	0.53 1.02 0.39	20.21 2.33 19.92	0.026 0.436 0.019	DE391BAB is "background" with sonde hanging in air. TD is 0.6 ft higher than 9/14/04. ^{137}Cs at TD identical to 9/14/84. ^{137}Cs generally at or below MDL. Possible ^{137}Cs at 231 to 233 ft.

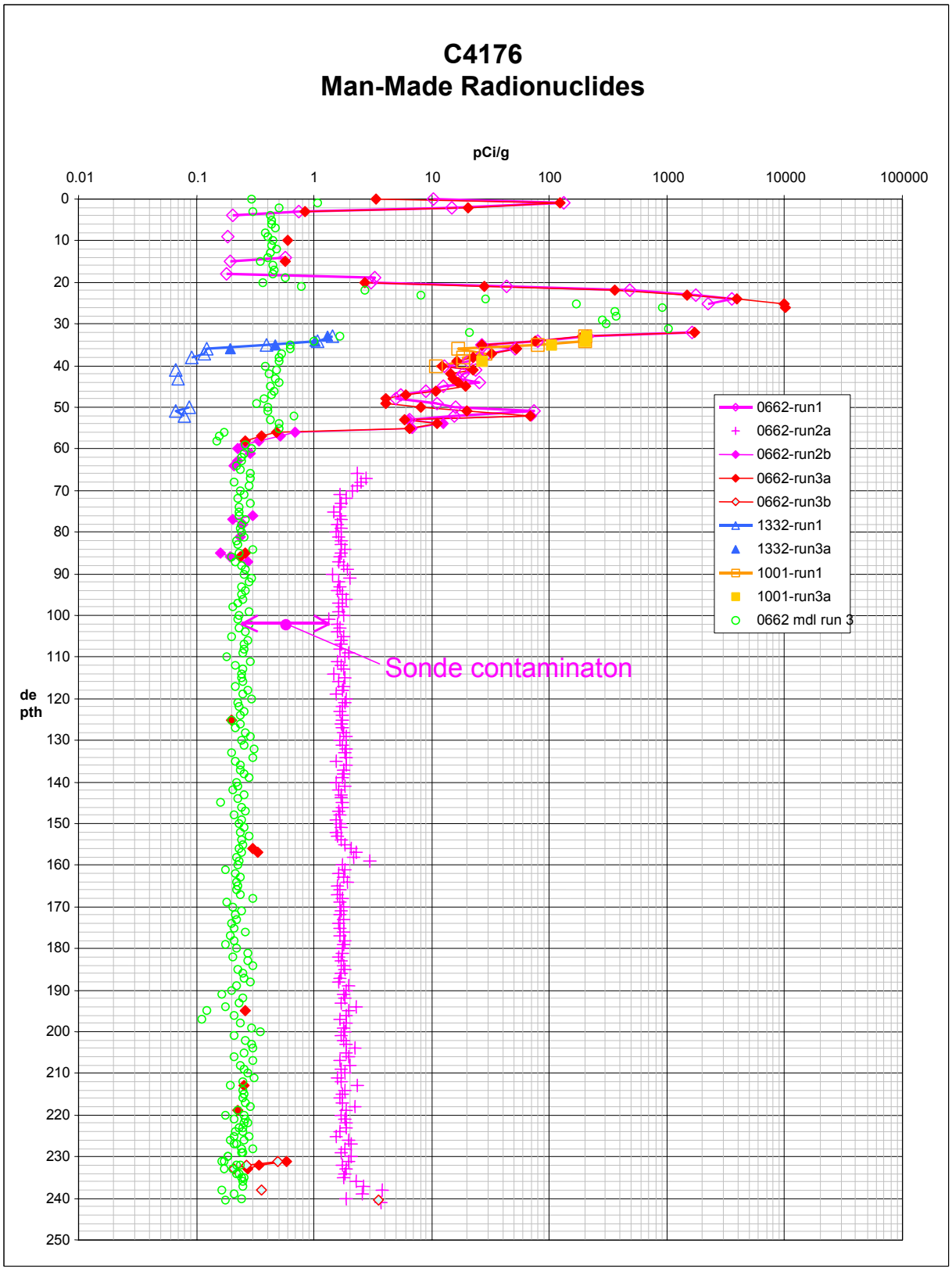
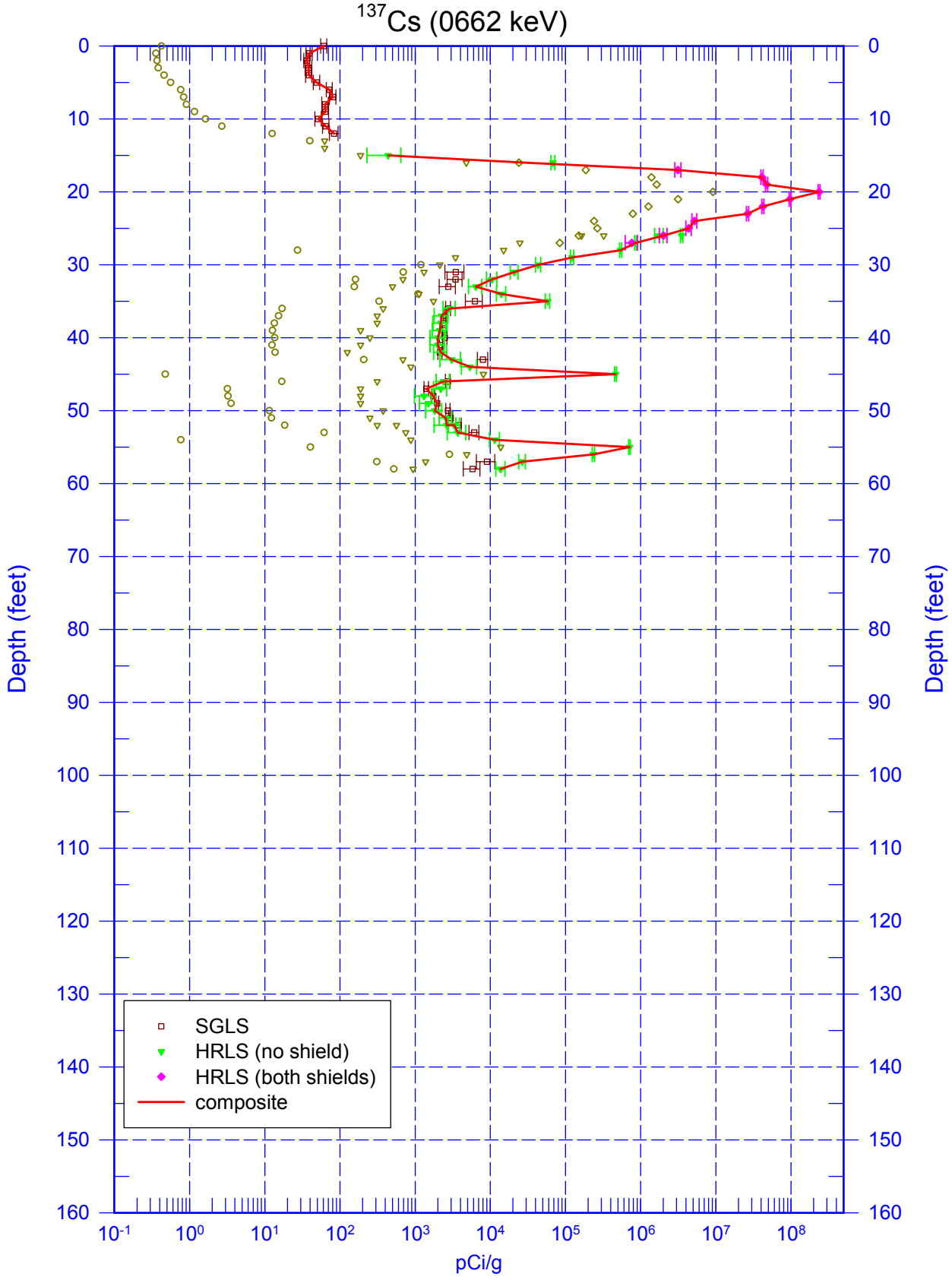


Figure 1. Preliminary Log Data C4176

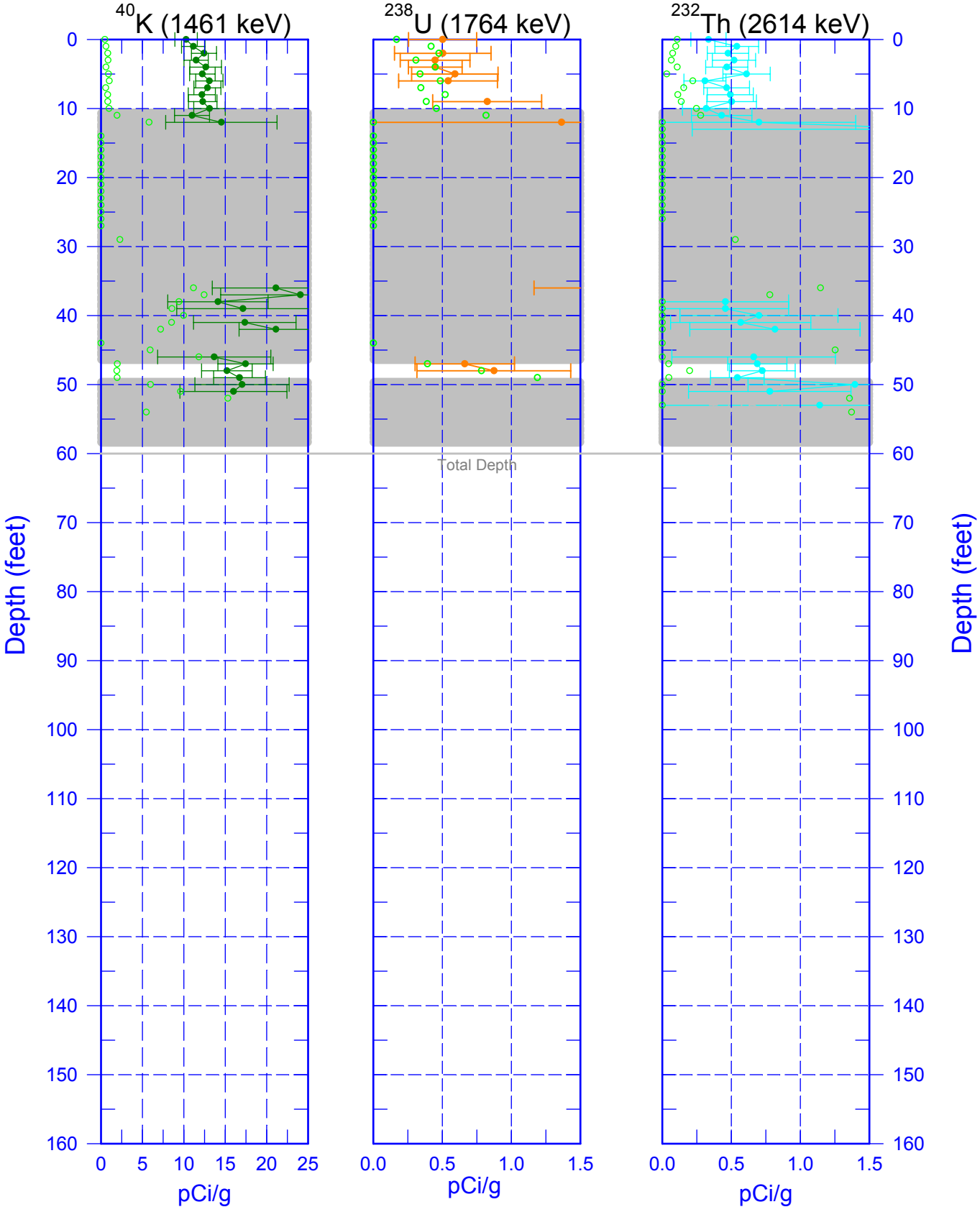
C4671
Man-Made Radionuclide



Zero Reference = Ground Surface

Last Log Date - 09/02/04

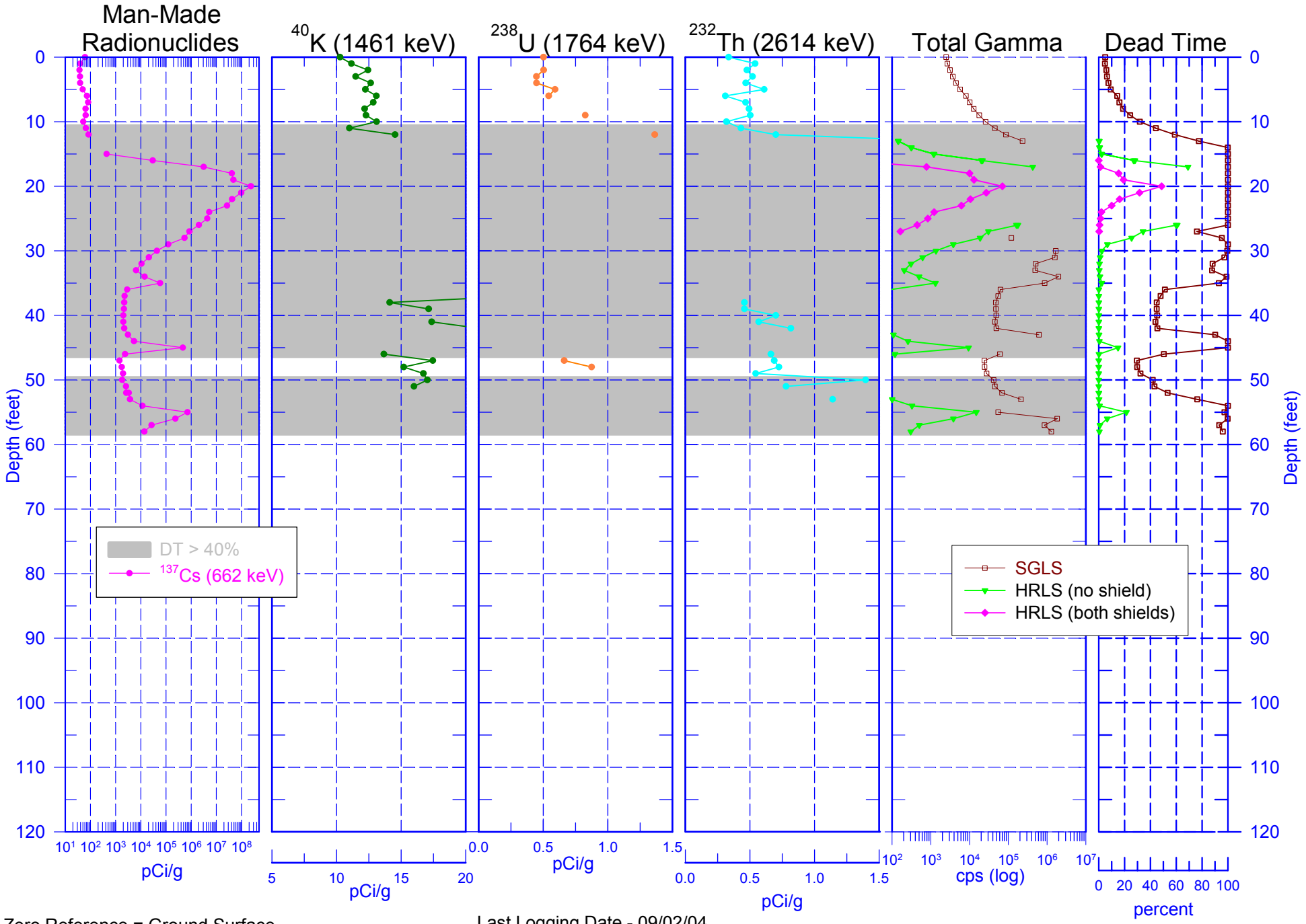
C4671
Natural Gamma Logs



Zero Reference = Ground Surface

Last Log Date - 09/02/04

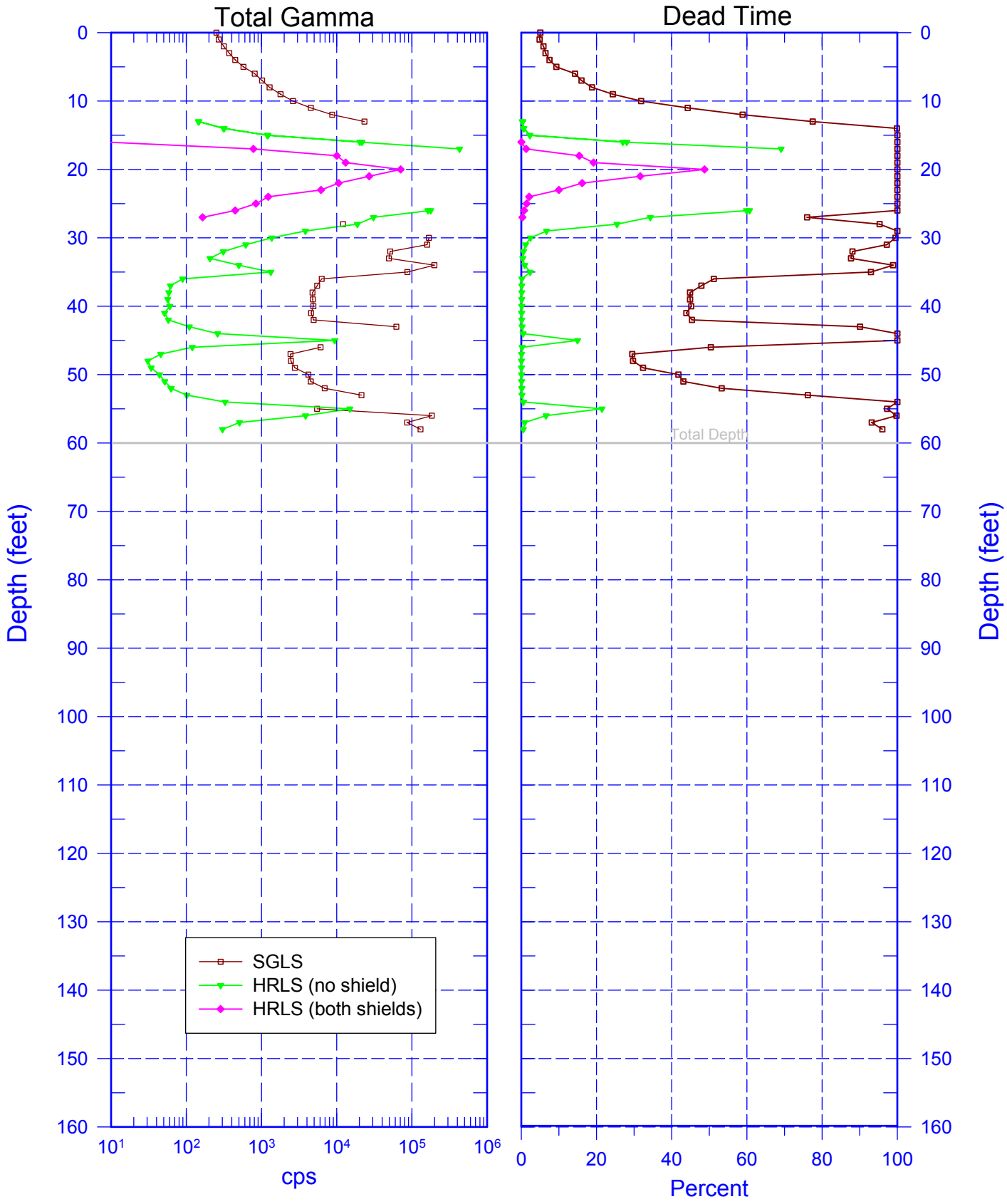
C4671 Combination Plot



Zero Reference = Ground Surface

Last Logging Date - 09/02/04

C4671
Total Gamma & Dead Time

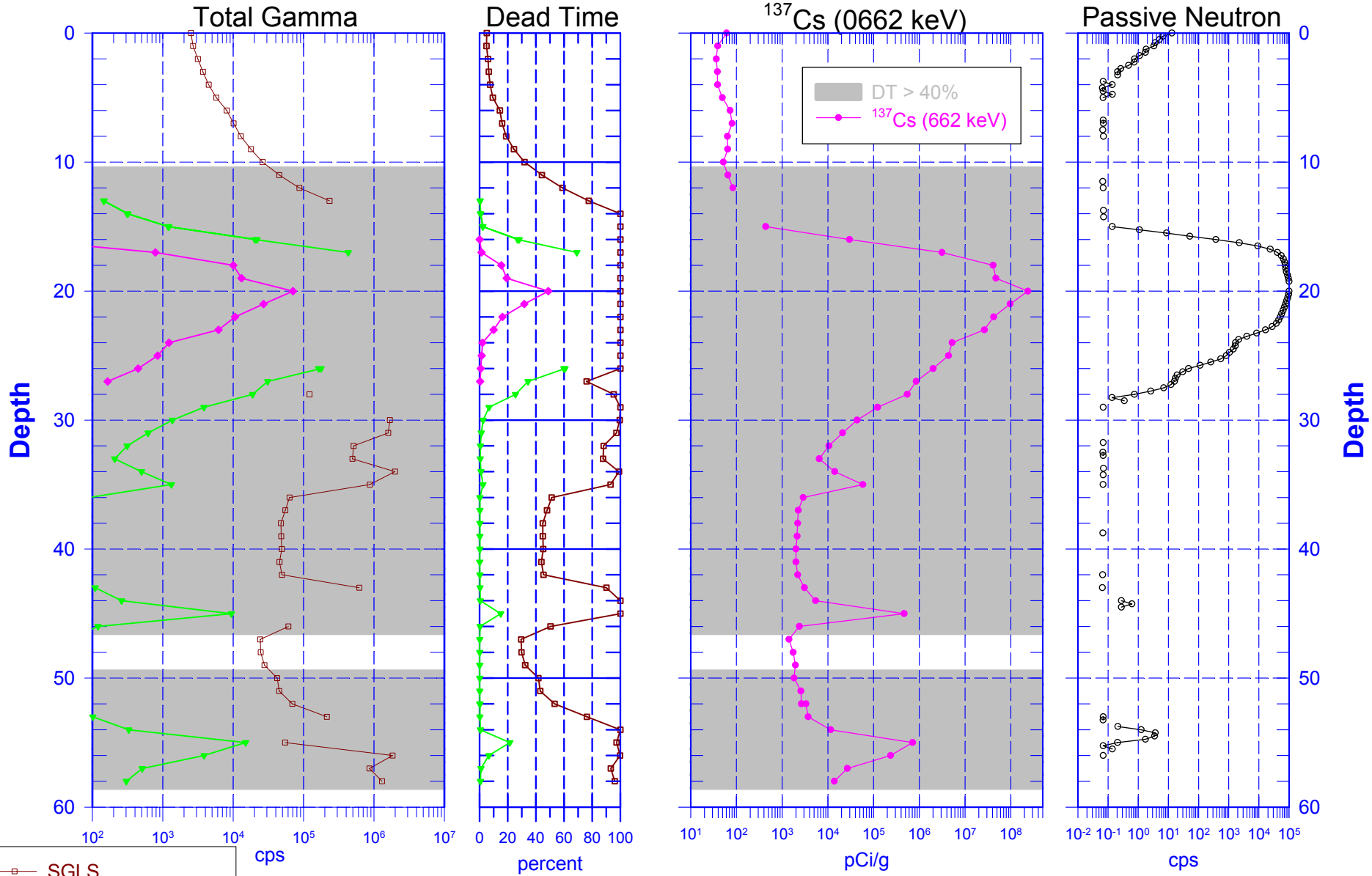


Zero Reference = Ground Surface

Last Logging Date - 09/02/04

C4671

Total Gamma, Man-Made Radionuclides, and Passive Neutron

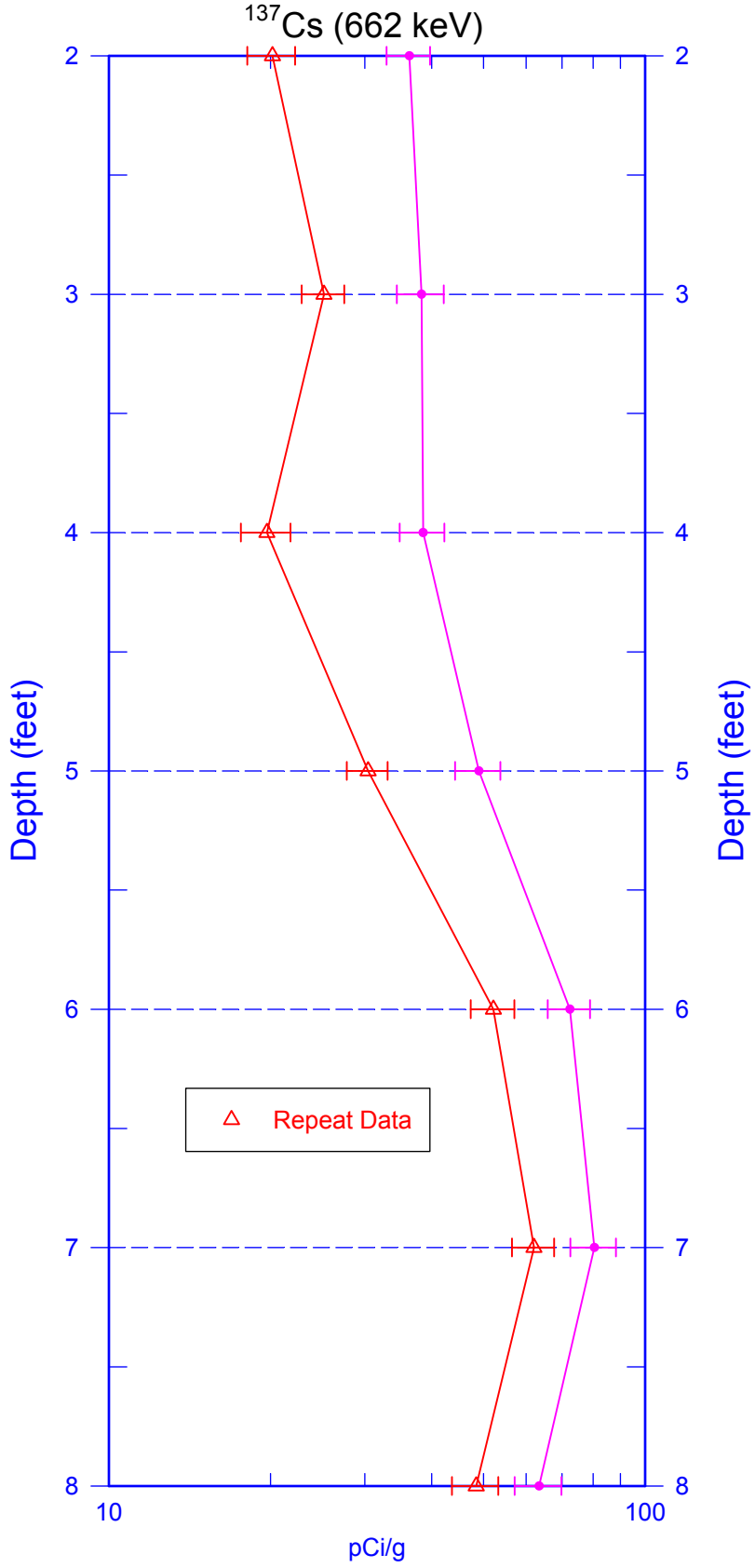


Zero Reference = Ground Surface

Last Logging Date - 09/02/04

C4671

SGLS Repeat Section: Man-Made Radionuclides

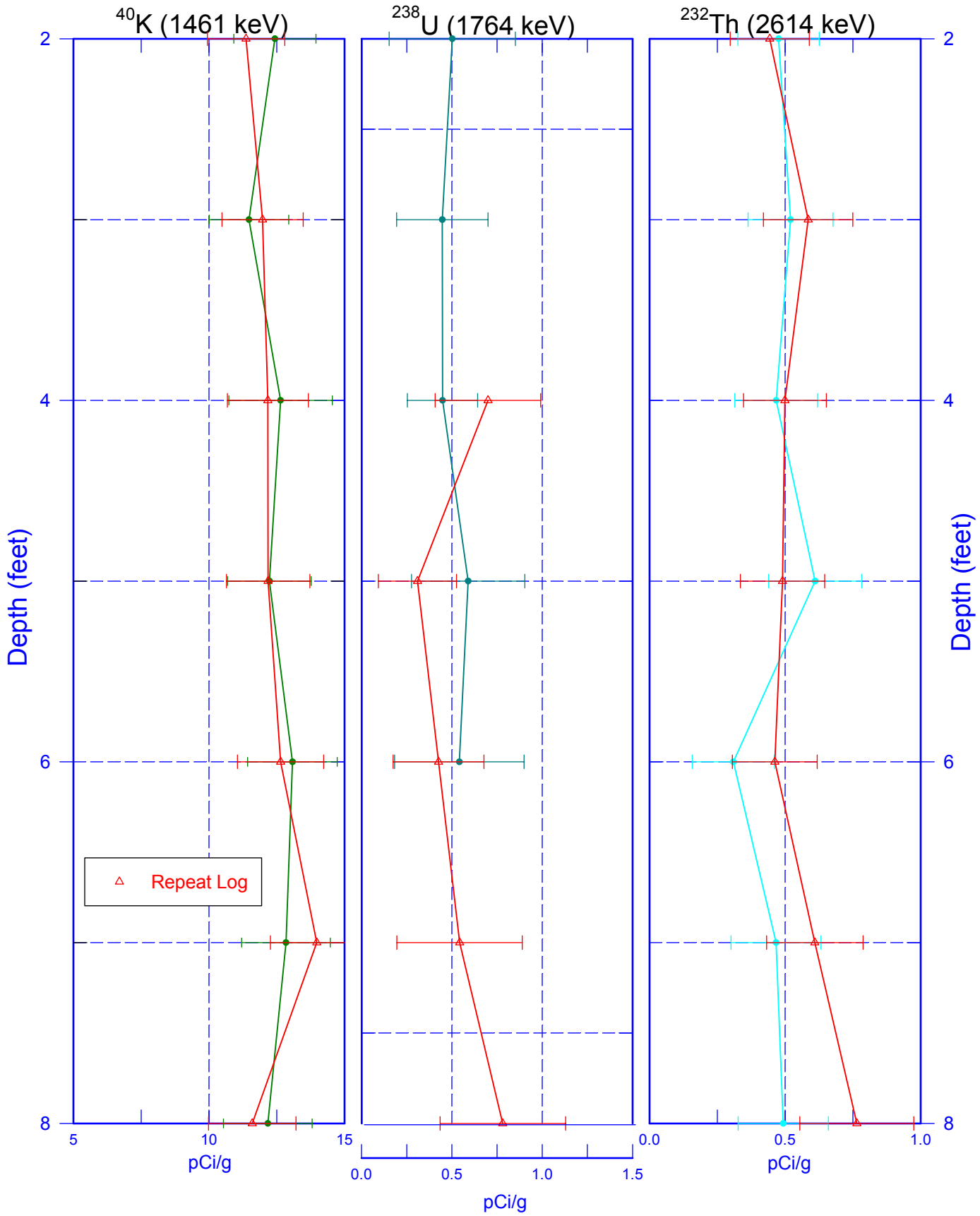


Zero Reference = Ground Surface

Last Log Date - 09/02/04

C4671

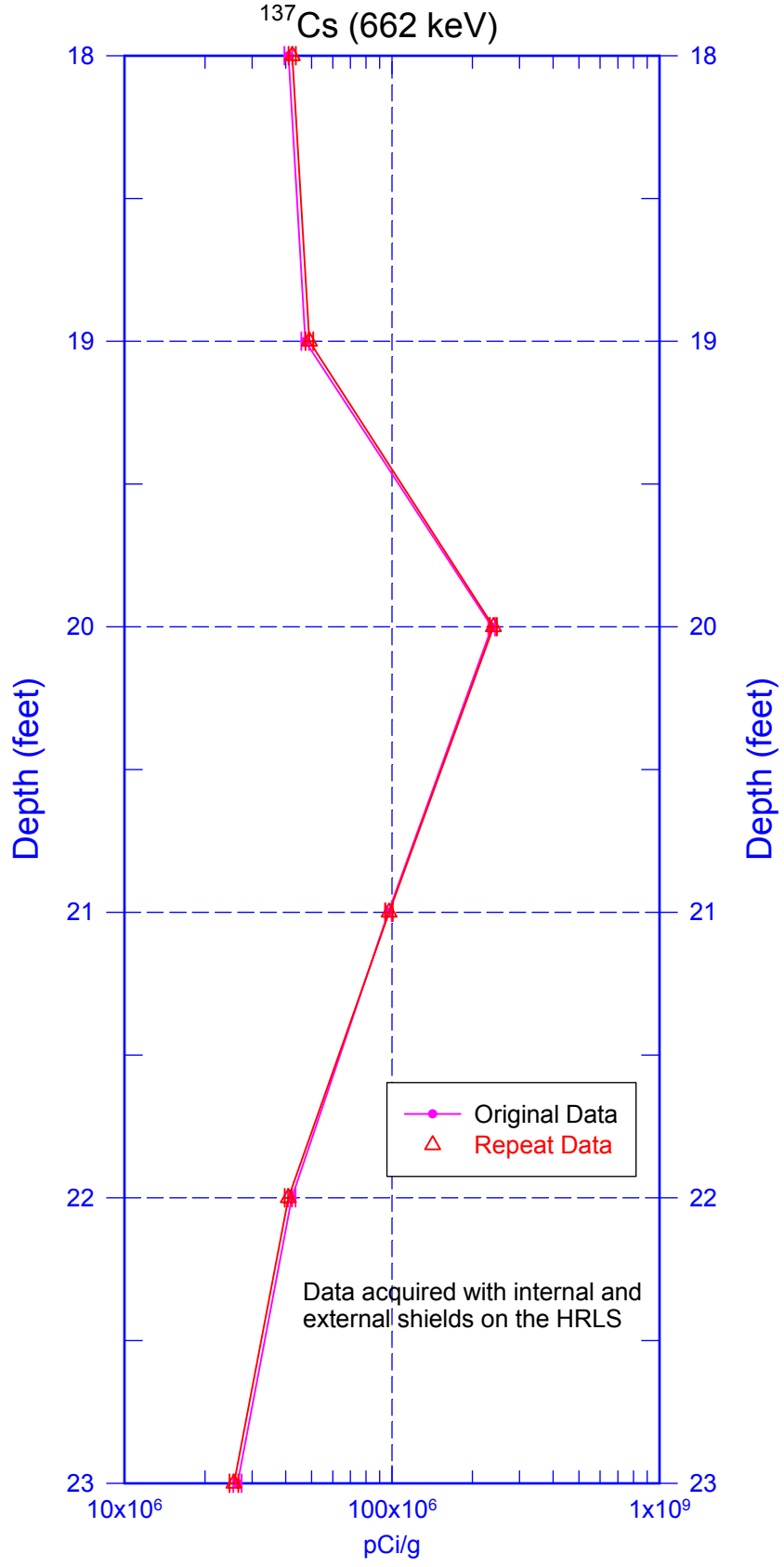
SGLS Repeat Section: Natural Radionuclides



Zero Reference = Ground Surface

Last Log Date - 09/02/04

C4671
HRLS Repeat Section: Man-Made Radionculide



Zero Reference = Ground Surface

Last Log Date - 09/02/04

C4176

Passive Neutron Count Rate vs. ^{137}Cs Concentration